Calculating Gamma Camera Uniformity Parameters: Beyond the Vendor-specific Protocol

Abstract

Objectives: The aim of this study was to develop and verify a personal computer-based software tool for calculating uniformity indices of gamma camera. **Materials and Methods:** The program was developed in MATLAB R2013b under Microsoft Windows operating system. Noise-less digital phantoms with known uniformity parameters were used to verify the accuracy of the program. Two hundred and forty-four Co-57 flood source images were acquired on Symbia T6 and Discovery nuclear medicine/computed tomography 670. The uniformity indices of these images were determined with their respective vendor's software and also by the tool developed. Bland–Altman plots were used for measuring the agreements between the developed program and the vendor's program for the calculation of uniformity indices. **Results:** The tool for calculating uniformity indices was found to be accurate. Uniformity indices measured with the tool revealed a very good correlation with vendor's software based on Bland–Altman analysis, as almost all measurements were within the ±2 standard deviation range. **Conclusion:** The software tool for calculation of uniformity indices is accurate, and the uniformity indices calculated by it are in agreement with uniformity indices calculated by the vendor's software.

Keywords: *Bland–Altman analysis, Co-57 flood source, Digital Imaging and Communications in Medicine, Gamma camera uniformity, MATLAB, National Electrical Manufacturers' Asssociation, personal computer-based software*

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Introduction

Ideally, a gamma camera provides uniform image of uniform flood source of activity such as Co-57 flood source. The performance of gamma camera is generally stable, though its performance may deteriorate anytime as it depends on the performance of the electronic components which can get affected by several factors, including environmental factors such as temperature and humidity.[1] Hence, before deploying gamma camera for clinical work, the performance of gamma camera is verified daily. The verification is done by acquisition of a uniform flood source of activity which is evaluated by visual inspection and/or by calculating uniformity indices such as differential and integral uniformity of the useful field of view (UFOV) and central field of view (CFOV).[2] Before deploying gamma camera for clinical work, it is important to ensure that the values of uniformity indices are within the acceptable limit.

There are several manufacturers of gamma camera. Our facility has gamma camera from two vendors: General electric (GE) Healthcare and Siemens nuclear medicine (NM). Both vendors have different protocols to acquire and process the flood source image. On Siemens camera, one has to acquire 10,000 K counts while on GE, acquisition of 4000 K counts is required to calculate uniformity indices of the flood source image. These protocols are just as per the recommendations of the corresponding vendors and therefore necessary in practice. The corresponding software is not configurable by the user to increase/decrease the number of counts to be acquired to find the uniformity indices.

We seek to inspect flood source image and calculate uniformity indices of this gamma camera by a tool developed for a personal computer (PC). Such tool shall give user freedom of experimentation and configuration as per his requirements. In this study, we developed and verified a PC-based tool for visually inspecting flood source images and calculating uniformity

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indices of the flood source image independent from the vendors' software.

Materials and Methods

MATLAB R2013b (The Math Works, Inc. 1 Apple Hill Drive Natick, MA 01760-2098, USA) running on Microsoft Windows operating system was used to develop the tool. MATLAB was selected because its image processing toolbox has several inbuilt functions to process an image in the Digital Imaging and Communications in Medicine (DICOM) format, and NM workstations have facility to export image data in DICOM format.

The calculation of uniformity indices such as integral and differential uniformity for the UFOV and CFOV of gamma camera is based on the National Electrical Manufacturers' Asssociation (NEMA) guidelines. It is pertinent to mention that the NEMA guidelines prescribe that flood source image should be stored on a matrix size which produces 6.4 mm ± 20% square pixels (approximately 60 pixels over 380 mm).[3] The acquisition protocols of different camera vary (for example, Siemens NM uses 1024 × 1024 matrix and GE Healthcare uses 256 × 256 matrix). To maintain the NEMA guidelines, the image is pulled into 64 × 64 matrix, which gives the pixel size for both Siemens and GE camera in the prescribed range of 6.4 mm ± 20% square pixels. The stepwise description of the developed program is given in Table 1. The average time taken by the program to determine the uniformity indices was determined by executing the program twenty-five times with same input image and recording the execution time.

Noise-less digital phantom with known uniformity indices was used. With this image as input, the intermediate results of the program were calculated by the hand. The program was also tweaked to display intermediate results. The hand calculation results and the program calculated results were compared to verify the accuracy of the program. The noise-less digital phantom images used to verify the program is given in Figure 1.

Symbia T6 is a dual head gamma camera with single photon emission computed tomography/computed tomography (SPECT/CT) facility. A 10000 K counts Co-57 flood source image in 1024 × 1024 matrix on each head was acquired using low energy high-resolution (LEHR) collimator. Uniformity indices (UFOV and CFOV integral and differential uniformity) were calculated using vendor's software. Forty-four flood source study (one study per day, total 88 flood source image) acquired on Symbia T6 were exported in DICOM 3.0 format. Discovery NM/CT 670 is a dual head gamma camera with SPECT/CT facility. Seventy-eight flood source studies (one study per day, total 156 Co-57 flood source images, 4000 K counts each, 256 × 256 acquisition matrix) acquired using LEHR collimator were exported in DICOM 3.0 format.

Uniformity indices calculated for the images acquired above by our tool were compared for agreement with uniformity indices obtained from the corresponding vendor's software. Whether two methods give comparable results was analysed using Bland-–Altman plots at 95% limits of agreement, that is, ±2 standard deviation (SD).[4]

Results

The developed PC-based tool runs in command window of MATLAB. It accesses the metainformation from the DICOM file such as total counts, study date, manufacturer and station of the gamma camera on which flood source has been acquired and displays these besides the integral and differential uniformity of the UFOV and CFOV.

The calculation of uniformity indices is based on methodology described by the technical documents published by the NEMA.[3] A set of twelve noise-less digital phantoms [Figure 1] were used to verify the accuracy of the program. The execution of the program took an average of 0.461092 s (SD = 0.005977, range: 0.4560–0.4744 s, $N = 25$) to process the dual head flood source image that was acquired on Discovery NM/CT 670. Each image was in 256 × 256 matrix having total count 4000 K. To process the dual head flood source image data acquired on Symbia

Table 1: Algorithm used to develop the program for calculating uniformity indices

Step No.	Description
Step 1	Clear memory, variables, command line
Step 2	Read flood source image
Step 3	Read pixel spacing in X and Y direction, number of pixels in X and Y direction, UFOV dimension in X and Y direction from the DICOM metadata information
Step 4	Extract UFOV image from the flood source image
Step 5	Pull flood source image data into 64×64 image matrix
Step 6	Use linear interpolation method to sample data at pixel spacing 6.4 mm
Step 7	Smooth the image obtained at the end of Step 6 using smoothing kernel (1 2 1; 2 4 2; 1 2 1)
Step 8	Calculate integral and differential uniformity using the formula given in the NEMA NU 1-2001
Step 9	Display the result

UFOV: Useful field of view, DICOM: Digital Imaging and Communications in Medicine, NEMA: National Electrical Manufacturers' Asssociation
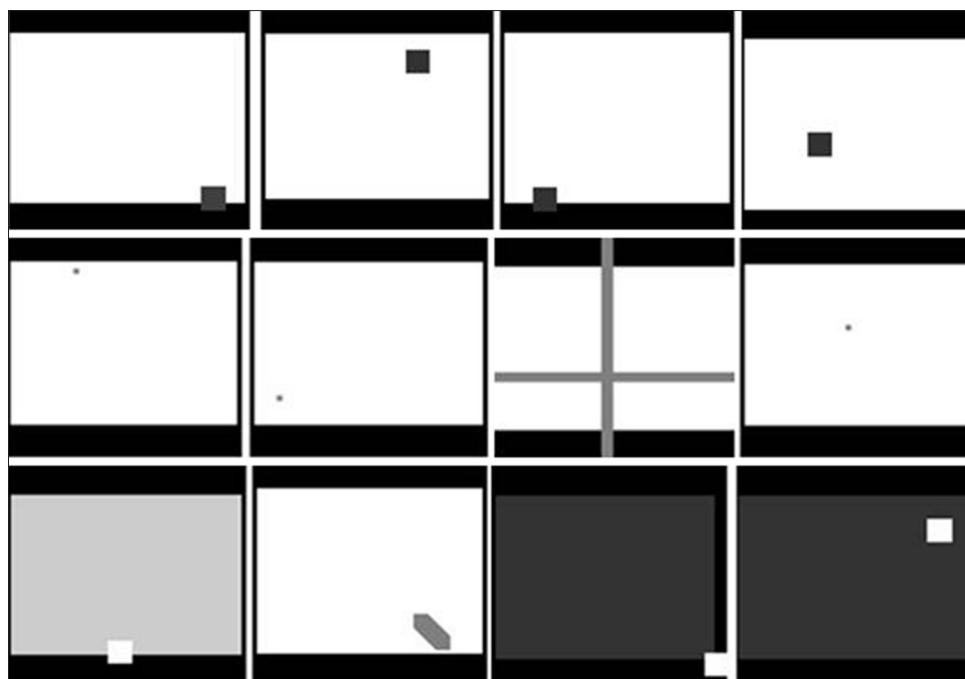
Figure 1: Noiseless digital phantom images used to verify the accuracy of the calculation
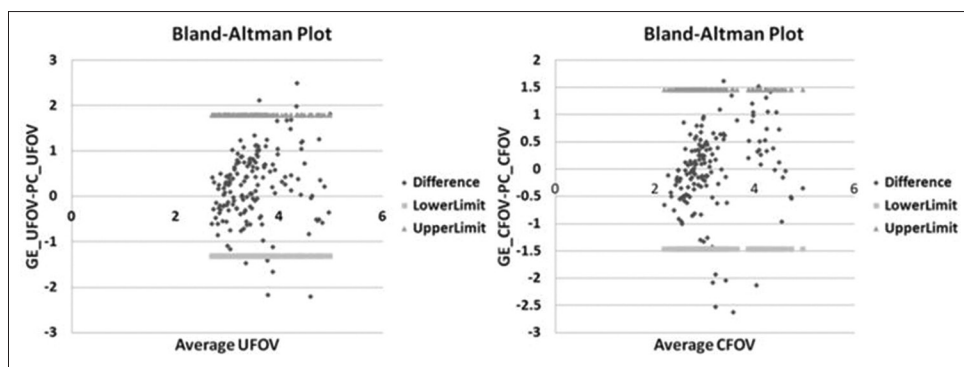

Figure 2: Bland–Altman plot for images acquired on general electric gamma camera

T6, it took an average of 0.537532 s (SD = 0.008863, range: 0.5243–0.5637 s, $N = 25$). It is to be noted that on Siemens gamma camera, the flood source data were in 1024×1024 matrix having total counts as 10000 K.

Bland–Altman plots were used for measuring the agreement between the calculated uniformity indices by our tool and those obtained from vendor's software. For this purpose, 244 extrinsic Co-57 flood sources images (156 acquired on Discovery NM/CT 670, GE Healthcare and 88 on Symbia T6, Siemens NM) were used. Uniformity indices calculated using our software had good level of agreement with the vendor's software based on Bland–Altman analysis, as almost all measurements were within the ±2 SD [Figures 2 and 3].

Discussion

The purpose of quality control (QC) is to detect changes in the performance of a gamma camera system that may adversely affect the interpretation of clinical studies. The system uniformity is the most important and sensitive QC parameter of gamma camera. Integral and differential uniformity parameters calculated from flood source image are most commonly used method to monitor the gamma camera uniformity daily.[5-7] The acquisition and processing of daily uniformity test of gamma camera are vendor-specific.

Based on Bland–Altman analysis, uniformity indices calculated by the developed program revealed a good level of agreement with indices obtained from the vendor's software. Almost all measurements were found to be within the ±2 SD range [Figures 2 and 3]. Siemens software calculates integral and differential uniformity for the UFOV and CFOV; however, GE software provides uniformity for UFOV and CFOV and does not mention about integral and differential uniformity parameters separately. Our PC-based software evaluates integral and differential uniformity for UFOV and CFOV.
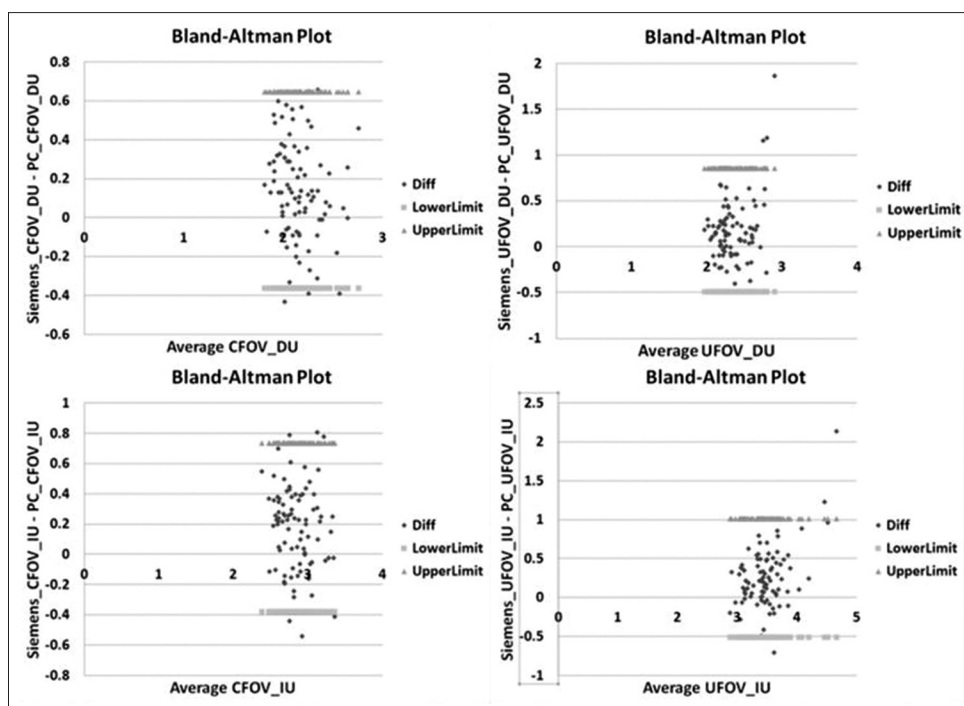
Figure 3: Bland–Altman plot for images acquired on Siemens nuclear medicine gamma camera

Rova *et al*.[8] have also developed the NEMA-based software for gamma camera QC. Their program has a graphical user interface whereas our program has a command window interface. Both programs calculate the integral and differential uniformity for both the UFOV and CFOV of gamma camera, but the way of presentation of results is different. Although it is mentioned that their program's result agree with comparable analysis by the manufacturer's software, supporting data are not reported in the paper.

With the help of this program, one can alter or reformulate one's own in-house protocol (that is, the total number of counts to be acquired in the flood source image) to record the daily variation of uniformity parameters, suitable, and acceptable to one's facility. Using our tool, system uniformity images acquired from different gamma cameras, irrespective of the vendor, can be processed in the same manner, and system uniformity of each gamma camera can be studied.

Using this tool, our future plan is to conduct a detailed study to find the size of acquisition matrix and the minimum counts to be acquired in a flood source images to perform daily uniformity tests.

Conclusion

The developed program for calculation of uniformity indices is an accurate tool and the uniformity indices so calculated are in agreement with uniformity indices calculated by the vendor's software.

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